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Floristic Quality Index of Restored Wetlands in Coastal Louisiana

Glenn M. Suir and Charles E. Sasser

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Abstract

Restoration efforts in the United States have created or benefitted large expanses of wetlands. Typical goals of wetland restoration efforts are to conserve, create, or enhance wetland form and to achieve wetland function that approaches natural conditions. Measures of wetland condition have been used to monitor and assess project performance, resilience, and adaptive management needs. An emerging tool for performing bioassessments in wetland systems is the Floristic Quality Index (FQI). This study assessed the use of a modified FQI (FQI_{mod}) to evaluate site development, plant community establishment, and wetland condition. Three restoration sites in coastal Louisiana were used to evaluate the utility of an FQI_{mod} for assessing the performance and resilience of restored wetlands by comparison to reference wetlands. Results demonstrate that the FQI_{mod} data successfully reflected large disturbance events — namely hurricanes and salinity spikes. The data also identified vegetation differences due to elevation, age, and hydrology. The modified FQI provided useful measures of restoration type (e.g., planted versus not planted, marsh creation versus nourishment), chronosequence (condition and stability over time), and trajectory (i.e., intersecting trend lines when restored marsh FQI approaches reference marsh condition). The FQI_{mod} provides a rapid and effective system for assessing wetland condition and performance.

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Preface

The work reported herein was conducted as part of the Ecosystem Management and Restoration Research Program (EMRRP). The EMRRP is sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Research and Development Center (ERDC) under the purview of the Environmental Laboratory (EL), Vicksburg, Mississippi. The EMRRP is managed under the Civil Works Environmental Engineering and Sciences Office, Dr. Alfred F. Cofrancesco, Technical Director. Dr. Trudy Estes was Program Manager of the EMRRP. The program monitor during this study was Mr. Timothy R. Toplisek, HQUSACE; the USACE Proponent for EMRRP is Ms. Mindy Simmons.

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Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second

1 Introduction

1.1 Background

Wetlands in the United States were once viewed as nuisance wastelands that bred disease, restricted overland travel, and hindered development; consequently, many were drained and farmed or developed by the first European settlers (Dahl and Allord 1996). Due primarily to these conversions, the amount of wetlands in the conterminous United States was reduced from approximately 221 million acres in the early 1660s, to an estimated 110 million acres by the year 2010 (Dahl and Allord 1996, Dahl 2010). Some wetlands, like those in coastal Louisiana, have experienced significant loss not only due to human activity but also to natural processes. The 1.2 million acres of wetlands lost in coastal Louisiana from 1932 to 2010 (a net wetland change of -25%) can be attributed to an assemblage of factors. The primary factors consist of subsidence, sea-level rise, hurricanes, floods, oil and gas exploration and extraction, salt water intrusion due to channelization, and sediment and nutrient deprivation due to flood protection measures (Couvillion et al. 2011).

In the last half century, research has shown that these “wastelands” are actually among the most productive and beneficial ecosystems in the world. Wetlands provide benefits that range from regulating services (floods, drought, and land degradation); supporting services (soil formation and nutrient cycling); provisioning services (food and freshwater); and cultural services (recreational and aesthetic); to maintaining high biological productivity and serving as critical habitat for fish and wildlife (Millennium Ecosystem Assessment 2003, USACE 2013). With an increasing understanding of wetland importance, federal and state governments enacted a number of policies, regulations, and incentive programs to directly and indirectly protect, maintain, and restore the wetlands of the United States (Votteler and Muir 1996). Many federal and state agencies and local stakeholders share responsibilities for maintaining or restoring the Nation’s wetlands.

In the United States, restoration efforts began small but soon developed into larger authorities and programs such as the Coastwide Wetland Planning and Protection Restoration Act (CWPPRA); the USACE Beneficial Use of Dredged Material (BUDM) programs; and state-led

master plans. In Louisiana, CWPPRA and BUDM programs have created or benefitted nearly 100,000 acres of wetlands collectively (Louisiana Coastal Wetlands Conservation and Restoration Task Force (LCWCRTF) 2015a). Additionally, the Louisiana Coastal Master Plan conservatively estimates (depending on future coastal conditions) that over 371,000 acres of land will be created or nourished using numerous restoration measures (Coastal Protection and Restoration Authority of Louisiana 2012).

Typical goals of wetland restoration efforts are to conserve, create, or enhance wetland form and to achieve wetland function that approaches natural conditions. Though wetland form and function are driven by many factors, the dominant factors include elevation, hydrology, sedimentation, and vegetation (USGS 1997). For a constructed wetland, failure to adequately manage one of these elements can negatively impact others, ultimately degrading wetland condition (Cohen et al. 2004).

Measures of wetland condition have been used to monitor and assess project performance, resilience, and adaptive management needs. There are three basic levels of wetland monitoring and assessment: 1) landscape assessment – which consists of coarse inventory information that is acquired and assessed using remote sensing and geographic information system (GIS) techniques; 2) rapid assessments – which are site-specific analyses using regionally derived and relatively simple and rapid protocols (e.g., Louisiana Wetland Rapid Assessment Method (LRAM)); and 3) intensive site assessments – consisting of research-derived, multi-metric indices that give detailed information about wetland function (e.g., the Hydrogeomorphic (HGM) Approach) (U.S. Environmental Protection Agency (USEPA) 2002b). Regardless of level, each assessment type provides metrics and indices that translate into descriptions of biological condition (Karr and Chu 1997). Landscape assessments are useful information when evaluating wetland change trajectories or analyzing direct episodic impacts across larger spatial and temporal scales. However, they may not be suitable for analyzing complex and dynamic systems. Conversely, intensive site assessments provide detailed information that are necessary for analyzing complex systems, but these assessments are customarily labor and resource intensive; unless high levels of detail are required, they can be unnecessary and impractical.

Rapid assessments are useful when general site-specific wetland ecological conditions are required. Evaluations of wetland ecological condition

require biological indices that measure or estimate wetland quantity and quality. Plants are excellent indicators of wetland function and condition because of their high levels of species richness, rapid growth rates, and direct response to environmental stressors and disturbances (Cohen et al. 2004, Mack 2007, Smith et al. 1995, USEPA 2002a). Specifically, plant species composition, cover, density, and biomass are structural components of coastal marshes that are commonly used to quantify vegetative characteristics and often serve as indicators of wetland condition (Chamberlain and Ingram 2012, Cretini et al. 2012). Though these structural components are useful for quantifying wetland characteristics, they are deficient at evaluating wetland quality. Wetland plant quality is an essential metric because it provides critical information related to habitats, effectiveness of restoration measures, resilience to disturbance events, and adaptive management needs and priorities (USEPA 2002a).

1.2 Approach

An emerging tool for performing bioassessments in wetland systems is the Floristic Quality Index (FQI). The FQI, a USEPA endorsed tool, has been used to identify areas of high conservation value, monitor critical landscapes, assess impacts from disturbance events, measure wetland ecological condition, assist in habitat restoration and mitigation policy, and compare restoration sites to reference sites (Bourdaghs et al. 2006, Fennessy et al. 2002, Gianopulos 2014). Where most other quality assessments are highly subjective, the FQI provides a rapid assessment that is a standardized, repeatable technique capable of comparing different vegetation and community types (Nichols 1999, Stapanian 2016). FQI provides an estimate of habitat quality based on a measure of vulnerability, called the Coefficient of Conservatism (CC), together with the richness or cover of a plant community (Gianopulos 2014). CC values range from zero (not conservative) to ten (conservative and highly ecologically sensitive), and are assigned to individual plant species within a local flora by a panel of experienced botanists, primarily based on their best professional judgment (Bourdaghs et al. 2006, Little 2013). Since the impact and function of plant species differ by region, CC values are specific to state or region (Little 2013). Table 1 provides the criteria that is typically used to assign CC values to individual plant species. Species are also assigned to general classes based on species characteristics. These classes include invasive plant species (CC value of 0), disturbance species (CC = 1–3), vigorous wetland communities (CC = 4–6), common species (CC = 7–8), and dominant wetland species (CC = 9–10).

Table 1. General description and criteria for assignment of Coefficient of Conservatism (CC) scores to different plant species (based on Andreas et al. 2004, Cohen et al. 2004, Cretini et al. 2012, and Swink and Wilhelm 1994).

General characteristics of species	Criteria	CC
Invasive plant species	Obligate to ruderal areas	0
Plants that are opportunistic users of disturbed sites	Occurs more frequently in ruderal areas than natural areas	1
	Facultative to ruderal and natural areas	2
	Occurs less frequent in ruderal areas than natural areas	3
Plants that occur primarily in less vigorous coastal wetland communities	Occurs much more frequently in natural areas than ruderal areas	4
	Obligate to natural areas (quality of area is low)	5
	Weak affinity to high-quality natural areas	6
Plants that are common in vigorous coastal wetland communities	Moderate affinity to high-quality natural areas	7
	High affinity to high-quality natural areas	8
Plants that are dominants in vigorous coastal wetland communities	Very high affinity to high-quality natural areas	9
	Obligate to high-quality natural areas	10

Various iterations of the Floristic Quality Index have been used to assess vegetation conditions across a wide range of geomorphic settings and ecosystems. The initial Floristic Quality Assessment Index (FQAI), developed by Swink and Wilhelm (1979), is a weighted metric that was developed to assess the quality of native plant communities (invasive species were not included in early FQI assessments). All native species within a sample site are used to calculate the FQAI as follows:

$$\text{FQAI} = \sum_i^s CC_i / \sqrt{N}_{native,} \qquad (1)$$

where CC_i is the coefficient of conservatism of species i, and N_{native} is the total number of native species found at the site (Andreas et al. 2004).

Appraisals of the FQI process have focused on the nature in which CC values are assigned to plant species. Numerous studies have been conducted to compare expert-panel-derived CC values and empirically derived values to assess the subjectivity and accuracy of the values (Bourdaghs et al. 2006, Cohen et al. 2004, Chamberlain and Ingram 2012, Mortellaro et al. 2012, Mushet et al. 2002, Rocchio 2007). These studies of bias have found the panel-derived CC method to be remarkably accurate when compared to data-driven assignments or rankings and ultimately provide adequate assessments of wetland condition (Gianopulos 2014).

Regardless of CC value subjectivity, Floristic Quality Indices are "human concepts" that have proven to be effective indicators of vegetation condition and are successful ecological assessment tools for detecting disturbance in wetlands (Bourdaghs et al. 2006, USEPA 2002a).

1.3 Objective

The majority of FQI applications have focused on monitoring natural and anthropogenic disturbance impacts on naturally occurring wetlands. However, with the increasing number of wetland restoration activities in the United States, there is a rising demand for rapid assessment methods of restored wetland condition and performance. To date, few FQI studies have assessed the condition of created or nourished wetlands. In 2012, Cretini et al. successfully used their modified FQI to assess vegetation condition in a managed system (hydrologic alteration). However, the immediate need is to establish the use and suitability of an FQI for evaluating the condition and evolution of created wetlands, and to ultimately link condition to key wetland structure and function metrics. The purpose of this study is to identify and apply a biological index that uses monitoring data to evaluate condition, performance (related to ideal ranges or targets), and resilience of restored wetlands, and compare those wetlands to naturally occurring reference wetlands. Validating the use of these traditional FQI applications for restored wetland monitoring and evaluations are requisite for future remote sensing-based FQI methods.

2 Methods

2.1 Study sites

Three study sites were utilized in this project. All sites consist of CWPPRA projects and surrounding areas (Figure 1). The first site, the Sabine Refuge Marsh Creation (CS-28) project and reference areas, consists primarily of intermediate and brackish wetlands that are located west of Hackberry, Louisiana. Hurricanes and canal building between 1956 and 1978 caused severe land loss in the area (Miller 2014). The Sabine restoration effort consists of five separate dredging cycles and creation sites (ranging in size from 125 to 230 acres) within an area of approximately 2,850 acres of open water. The creation sites, known as Cycles 1-5, were constructed in 2002, 2010, 2007, 2014, and 2015, respectively. At the time of sampling, only Cycles 1 (north) and 3 (south) contained vegetation, or vegetation survey data, so Cycles 2, 4, and 5 were not included in this study. Cycles 1 and 3 were constructed to an initial height of +2.7 to +3.1 ft North American Vertical Datum 1988 (NAVD88, Geoid 99) and allowed to consolidate and desiccate to a final target elevation of approximately +1.2 ft NAVD88 (Sharp 2003 and Miller 2014). After material consolidation and colonization of emergent vegetation, the containment dikes were breached to allow for hydrologic and fisheries access. The Cycles differ in that Cycle 1 was planted with 36,000 *Spartina alterniflora* plants around the perimeter and along the hydrologic and fish access channels (Miller 2014). Meandering and curving trenasses were also constructed within Cycle 1 (Sharp 2003). Conversely, vegetation and hydrology were allowed to occur naturally in Cycle 3.

The second site, Atchafalaya Big Island Mining (AT-03), consists of fresh water wetlands that are located southwest of Morgan City, Louisiana, within the Atchafalaya River Delta. The purpose of AT-03 was to enhance natural-delta-building processes by creating an avenue for sediment transport to areas north and west of the initial Big Island location (Curole 2003). In 1998, approximately 3.3 million cubic yards (cu yd) of material dredged from the Atchafalaya River was pumped into placement areas, at elevations between +3.27 ft and +1.77 ft NAVD88, and allowed to consolidate and desiccate to a final target elevation of +1.3 ft NAVD88 (Brown, Cunningham and Gannuch Inc. 1998), creating approximately 920 acres of new wetlands. Additionally, a secondary distributary channel, with four smaller tertiary channels, was constructed to emulate an emerging delta (Curole 2003). It was estimated that this restoration effort

would provide approximately 2,000 acres of wetland gains over the course of the project lifespan (LCWCRTF 2002).

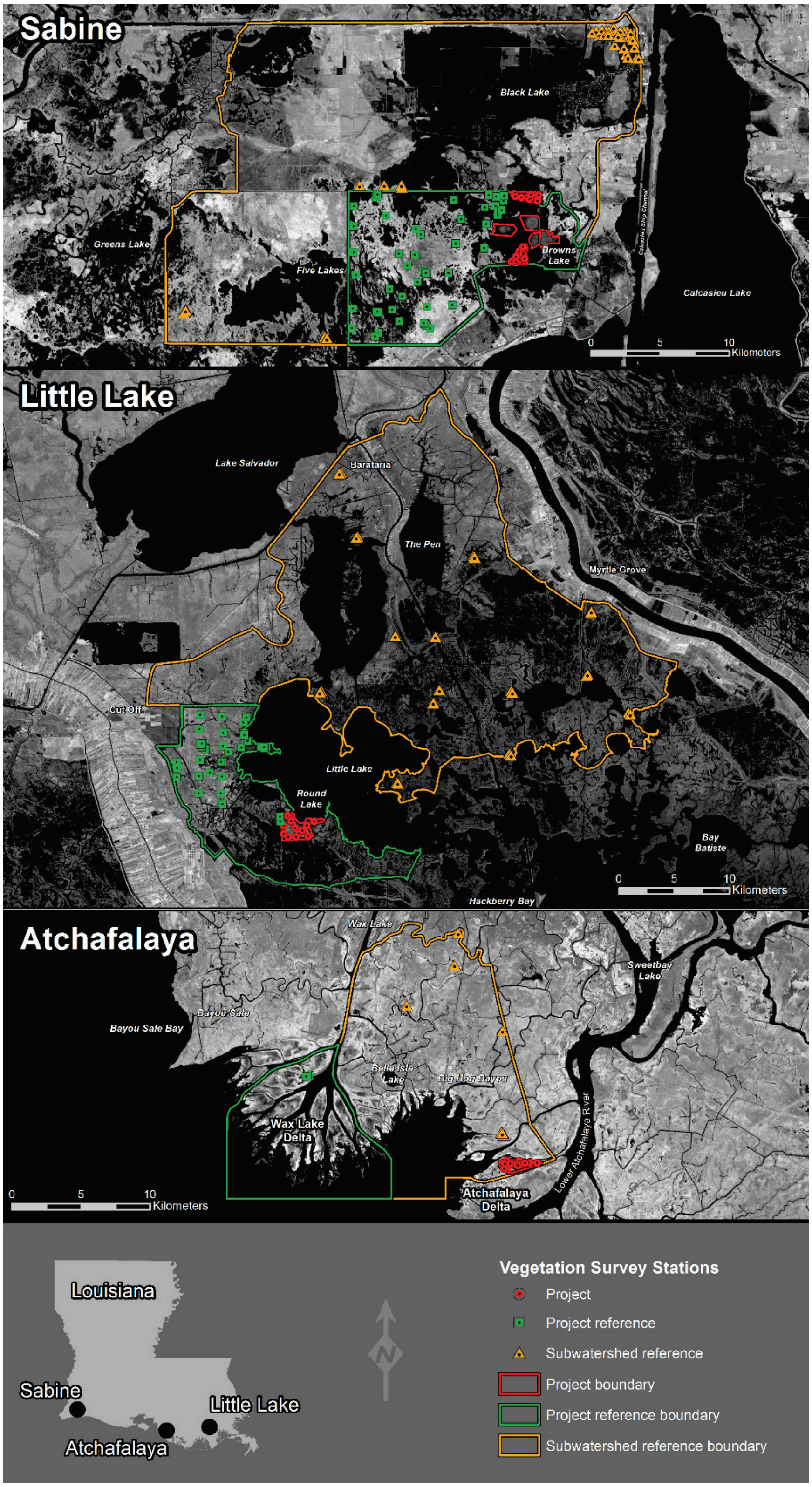
The third site, Little Lake Marsh Creation (BA-37), consists primarily of intermediate and brackish marsh (with recent transition to saline marsh along the southern fringe) located east of Cutoff, Louisiana. The project area consists of rapidly degrading Little Lake shoreline and Bayou L'Ours Ridge, which are protecting approximately 3,000 acres of fragile interior marshes (LCWCRTF 2015b). Shoreline erosion, subsidence, and channel construction in the Little Lake mapping unit has resulted in the loss of approximately 53% of total wetlands from 1932 to 1990 (NMFS 2001). In 2007, in an attempt to slow the erosion rate, material was hydraulically dredged from the bottom of Little Lake and pumped to the project fill area to create and nourish approximately 920 acres of marsh to an average fill elevation target of +2.1 feet NAVD88 (Louisiana Office of Coastal Protection and Restoration 2009). Within the first growing season after consolidation (2007), the created platform was vegetated with approximately 17,000 plugs of *Spartina alterniflora* (LCWCRTF 2015b).

2.2 Assessment units

Reference wetland sites serve as standards against which others are evaluated, and therefore they are critical components of all biological assessments (USEPA 2002a). Selection of appropriate or representative reference sites can be difficult; the use of multiple sites and scales can overcome some of the challenges of defining a reference standard for evaluating restoration performance (Matthews et al. 2009).

The assessment units used in this study consist of three varying scales (Figure 1); the Project, Project Reference (PR), and Subwatershed Reference (SR) units. The Project units consist of the pre-defined CWPPRA project boundaries. The PR units consist of CWPPRA established reference sites; existing or nearby wetlands that represent natural system processes and conditions. An example is the Atchafalaya study site's PR unit, which consists of the Wax Lake Delta (WLD). The WLD is a bayhead delta at the outfall of the Wax Lake Outlet, an artificial diversion of the Atchafalaya River (Carle 2013). Though the WLD and Atchafalaya Delta are both pro-grading deltas, the WLD is developing "naturally," while some of the islands within the Atchafalaya Delta were constructed (but receive significant riverine inputs). The SR units consist of generalized hydrologic units (HUC10) that are intersected with corresponding vegetation zones (Sasser et al. 2014) to represent natural wetland conditions and trajectories within larger watershed segments.

Figure 1. Location map of study areas (Sabine, Little Lake, and Atchafalaya), assessment units (Project, Project Reference, and Subwatershed Reference), and data collection sites.



2.3 Vegetation survey data

Vegetation was surveyed at all Project, PR, and SR stations. Where available, this study used existing CWPPRA and Coastwide Reference Monitoring Stations (CRMS) vegetation data and locations, otherwise new survey stations were created uniformly along existing elevation transects. The CWPPRA monitoring program established standardized methods for monitoring variables that are useful in determining the performance of wetland restoration projects. Though those methods have not included FQI assessments in their monitoring approach. The vegetation monitoring component of CWPPRA collects species composition, relative abundance, and aboveground biomass data (Steyer and Stewart 1992). Vegetation data are typically collected more frequently early in a project's life (yearly), and less frequently (every 3-5 years) as a project nears the end of its anticipated lifespan (CWPPRA projects are typically designed and constructed for 20-year lifespans). Similarly, CRMS is a network of 392 monitoring sites in coastal Louisiana that is used to collect, process, and analyze physical, chemical, biological, and geospatial data to characterize coastal wetland landscapes inside and outside of CWPPRA projects (Cretini et al. 2011). Within the CRMS program, emergent vegetation are surveyed annually during the period of peak biomass (Folse et al. 2014). All existing vegetation data from CWPPRA and CRMS stations were acquired for all Project, PR, and SR sites. For new data collections, vegetation species composition and percent cover were collected from within 0.25 m^2 quadrats at each project sample site during periods of peak biomass in 2014 and 2015.

2.4 Floristic quality index

Though the standard FQI does not include invasive species, more recent iterations of the FQI use these opportunistic species as indicators of disturbance. These inclusions are driven by research showing strong correlations between invasive species richness and human activity, hydrologic impairments, and floristic index scores (Ervin et al. 2006). The standard FQI also uses the number of native species as an abundance measure. However, some existing restoration monitoring systems do not collect abundance values; rather, the systems collect percent cover values as part of the systems' monitoring protocol (Folse et al. 2014). In 2011, a modified FQI, which incorporates invasive species, percent cover values, and accounts for total percent cover and overlapping canopies, was developed for coastal Louisiana (Cretini et al. 2012). This index uses a two-

pronged approach to account for sample units with vegetation cover that is less than or equal to 100% or is greater than 100% (overlapping canopies). If the sum of species covers within a sample unit at time *t* is less than or equal to 100, the applicable formula is as follows:

$$\mathrm{FQI}_{\mathrm{mod}\ t} = \left(\frac{\sum\ (\mathrm{COVER}_{it} \times \mathrm{CC}_i)}{100} \right) \times 10, \tag{2}$$

where $\mathrm{FQI}_{\mathrm{mod}\ t}$ is the modified floristic quality index (unitless), COVER_{it} is the percent cover (%) for species *i* at a sample unit, within a sample site, at time *t*, and CC_i is the Coefficient of Conservatism for species *i* (Table 1).

By using 100 in the denominator (instead of the actual sum of species covers), differentiation between wetlands of similar composition (e.g., vigorous wetlands) can be made using normalized biomass (estimated through cover) (Cretini et al. 2012). For consistency with other CRMS and CWPPRA metrics and indices, the FQI values are multiplied by 10 to scale the scores from 0 to 100 (Cretini et al. 2011).

If the sum of species covers within a sample unit at time *t* is greater than 100, the applicable formula is:

$$\mathrm{FQI}_{\mathrm{mod}\ t} = \left(\frac{\sum\ (\mathrm{COVER}_{it} \times \mathrm{CC}_i)}{\sum\ (\mathrm{TOTAL\ COVER}_t)} \right) \times 10, \tag{3}$$

where $\mathrm{TOTAL\ COVER}_t$ refers to the percent cumulative species cover (expressed as a percentage) within a sample unit (Cretini et al. 2012).

FQI score can provide measurements of vegetation condition and maturity. Low FQI values can be indicative of early successional vegetation communities, highly disturbed or early post-disturbance evolution, or other presses or pulses that are negatively impacting natural or managed wetlands. Conversely, high FQI values are more typical in mature, stable, and undisturbed wetlands.

For all established CWPPRA and CRMS stations within the Project, PR and SR assessment units, the CRMS Data Download service was used to acquire station-specific FQI data from 1997 to 2015 (Table 2) (CPRA 2016). These data were amended with vegetation surveys that were performed as part of this study (surveys conducted in 2014 and 2015). For existing and newly generated data, the CC values were applied and $\mathrm{FQI}_{\mathrm{mod}}$

was calculated for each vegetation station within the Sabine, Atchafalaya, and Little Lake Project, PR, and SR areas, using the Louisiana list and equations (Equations. 2 and 3, incorporating invasive species) developed by Cretini et al. (2011 and 2012). For species not on the Louisiana Coefficient of Conservatism list, established values from regional lists or neighboring states were used in conjunction with best judgement (Herman et al. 2006, Mortellaro et al. 2012, Gianopulos 2014).

3 Results and discussion

There were a total of 559 vegetation stations used in this study (Table 2), the majority consisting of CWPPRA and CRMS monitoring stations. The Sabine study site consisted of 45, 125, and 68 vegetation stations (238 total) in the Project, PR, and SR units, respectively. The Atchafalaya study site consisted of 42, 15, and 49 vegetation stations (106 total) in the Project, PR, and SR units, respectively. The Little Lake study site consisted of 30, 36, and 149 vegetation stations (215 total) in the Project, PR, and SR units, respectively. Vegetation surveys for all study sites began in the 1990s, but the number and frequency of surveys varied within and across assessment units (Table 2). Generally, fewer surveys were performed in the first half of the period of analyses (1997-2015), and increased in the second half. The CWPPRA and CRMS-based vegetation data were supplemented with surveys within the Project units in 2014 and 2015.

3.1 Community descriptions

3.1.1 Sabine vegetation

Historically, vegetation survey data have been used to identify the presence of and track changes in vegetative species and communities over time. Miller (2014) describes a 1968 to 1988 shift in the CWPPRA Sabine project area vegetation community from intermediate and fresh dominated marsh species to more brackish species, including *Spartina patens* (saltmeadow cordgrass), *Schoenoplectus americanus* (bulrush), and *Schoenoplectus robustus* (saltmarsh bulrush).

Figure 2 shows the average percent cover by species for all stations within assessment units by year. The figure also groups and color codes all species based on CC values. There were 85 different plant species observed across all Sabine units and stations from 1997 to 2015. Species with cover values <3% in a given year were categorized as “other.” Within the Project assessment unit, Cycle 1 was constructed in 2002 and its edges were planted with *Spartina alterniflora*. The Cycle vegetated quickly and by the first vegetation survey (2004) *Spartina alterniflora* accounted for 57.5% of a total cover of 59.5%. Hurricanes Lili (Category 1 storm, October 3, 2002) and Rita (Category 3 storm, September 24, 2005) significantly impacted vegetation communities along the central and western portions of coastal Louisiana. Hurricane Rita reduced the percent cover within Project sites to

1.8% in 2005, but those sites recovered to 90% and 81.5% cover by 2006 and 2007, respectively. *Spartina alterniflora* remained the dominant species during this recovery, accounting for 90% and 76.6% of the total cover, respectively. By 2008, the *Spartina alterniflora* monoculture within the Project sites began to shift to a vegetative assemblage of common (CC = 7-8) and dominant (CC = 9-10) species. This was due in part to the construction (2007) and natural colonization of Cycle 3. From 2011 to 2015, the typical vegetation profile for Project sites had total cover values between 75% and 87%, and consisted primarily of *Spartina alterniflora*, *Distichlis spicata*, *Schoenoplectus robustus*, *Borrichia frutescens*, *Iva frutescens*, and nominal percentages of "other" species.

Table 2. Number of vegetation survey stations within each study site and assessment unit.

	Sabine			Atchafalaya			Little Lake		
Date	Project	Project Reference	Subwatershed Reference	Project	Project Reference	Subwatershed Reference	Project	Project Reference	Subwatershed Reference
1997	0	0	45	0	0	4	0	0	0
1998	0	0	0	0	0	0	0	0	0
1999	0	58	5	20	0	0	0	17	0
2000	0	0	0	0	0	0	0	17	0
2001	0	17	0	0	0	0	0	0	0
2002	0	17	0	17	0	0	0	17	0
2003	0	0	0	0	0	0	0	0	0
2004	14	72	2	0	0	0	0	0	0
2005	6	10	0	0	0	0	0	17	0
2006	7	57	10	0	0	10	0	10	60
2007	7	60	13	17	10	46	0	10	80
2008	12	60	16	0	10	46	10	27	80
2009	10	50	16	0	10	48	10	10	80
2010	22	69	20	0	10	49	9	10	80
2011	10	50	18	0	10	49	9	10	80
2012	26	68	15	0	10	47	8	27	80
2013	10	50	15	0	9	42	8	10	80
2014	26	70	15	12	12	46	20	13	80
2015	10	50	16	20	13	44	12	12	80
Total Stations	45	125	68	42	15	49	30	36	149

The first vegetation surveys in the Sabine PR assessment unit occurred in 1999 and exhibited a total of 88.6% vegetation cover. The PR sites consisted primarily of *Spartina patens* (14.9%), *Distichlis spicata* (8.8%), *Schoenoplectus americanus* (7.8%), *Schoenoplectus robustus* (7.4%), and the "other" class, which consisted of 22 species and accounted for 26.1% of the cover. By 2001 and 2002, the PR sites were dominated by *Schoenoplectus americanus* and *Distichlis spicata*, with some lower percentages of *Spartina patens* and *Paspalum vaginatum* (seashore paspalum). By the 2005 surveys, the average total cover per site decreased to 44.4% and consisted of only two species, *Spartina patens* and *Paspalum vaginatum*. This change in cover was directly related to hurricane impacts. From 2006 to 2015, the PR sites exhibited a slow recovery and reestablishment of vegetation, with higher percentages of the "other" class, followed shortly by increasing percentages of disturbance species (CC = 1–3) and more recently by vigorous wetland species (CC = 4–6).

In 1997, the SR stations consisted primarily of *Schoenoplectus californicus*, (19.1%), *Spartina patens* (15.4%), and *Paspalum vaginatum* (7.7%). The SR stations in 1997 consisted of 31 species that were categorized as "other," accounting for 20.9% of the total cover. The dominant species persisted throughout the period of study, but they were occasionally equaled or surpassed in cover by *Iva frutescens* (Jesuit's bark; max 14%), *Distichlis spicata* (Coastal Salt Grass; max 11.9%), and *Leptochloa fusca* (Malabar sprangletop; max 22.1%).

For the Sabine sites, the Project unit experienced rapid vegetation establishment followed by a transition to higher diversity and colonization by common and dominant species. The PR and SR units were dominated by common and dominant species prior to Hurricane Rita. However, the PR unit transitioned to dominant with vigorous wetland species while the SR unit transitioned to assemblages with higher numbers of disturbance species with higher percentages of cover.

3.1.2 Atchafalaya vegetation

Historically, two general herbaceous vegetation associations, Sagittaria and Typha, have dominated the natural Atchafalaya Delta islands (Johnson et al. 1985). The Sagittaria association, which typically occurs at the lowest intertidal elevations, consists of *Sagittaria latifolia* (duckpotato), *Sagittaria platyphylla* (delta duckpotato), and *Schoenoplectus americanus* (previously known as Scirpus americanus,

three-cornered grass) (Curole and Babin 2010). The Typha association, which consists of *Typha latifolia* (broadleaf cattail), *Cyperus difformis* (cyperus), *Eleocharis spp*. (spikerush), *Scirpus validus* (softstem bulrush), and *Ammannia coccinea* (ammannia), typically occurs at intermediate elevations (Curole and Babin 2010).

Figure 3 shows the average percent cover by species for all stations within assessment units by year for the Atchafalaya study site. There were 112 unique plant species observed across all units and stations from 1999 to 2015. The Atchafalaya Big Island mining wetlands were constructed in 1998 and the first Project vegetation surveys were performed in 1999. The total cover for the first survey was 78.5% and dominated by disturbance and vigorous wetland species. Those species included *Leptochloa panicoides*, *Nelumbo lutea*, and *Potamogeton nodosus,* each accounting for 10.3% cover, as well as *Sphenoclea zeylanica*, *Heteranthera dubia*, and *Myriophyllum spicatum*, each accounting for slightly more than 6% cover. In 1999, the sites also consisted of 20 "other" class species, accounting for 15.3% of the total cover. The effects of Hurricane Lili are observed in the 2002 survey data, which show the total cover was reduced to 35.3%. By the 2007 survey, the Project area total percent cover increased to pre-hurricane levels, and the dominant species remained invasive and in rigorous communities. Though this trend of invasive and rigorous species continued, the dominant species shifted to *Typha latifolia* (24.2% cover), *Zizaniopsis miliacea* (22.2%), *Ludwigia leptocarpa* (13.4%), and *Bidens laevis* (11.2%) in 2014, then to *Heteranthera* (19.5%), *Nelumbo lutea* (11.5%), *Hypoxis sessilis* (11.0%), and *Colocasia esculenta* (10.4%) by 2015.

The PR area, which consists solely of the Wax Lake Delta CRMS survey sites, began collecting annual data in 2007. The cover and dominant species within the PR sites remained consistent from 2007-2012, with the total percentages ranging from 79.1% to 91.1% per year. The dominant species during this period were in the invasive and rigorous communities and consisted of *Alternanthera philoxeroides*, *Bidens laevis*, *Colocasia esculenta*, *Ludwigia peploides*, *Polygonum punctatum*, and *Sesbania drummondii*. The 2013 survey shows that the majority of the total cover was dominated by the invasive *Colocasia esculenta*. This shift in vegetation could be the result of disturbance events, particularly the major Atchafalaya River flood in 2011 and Hurricane Isaac (Category 1), which made landfall on August 28, 2012. The 2014 and 2015 surveys show sites

that increased in cover by rigorous species, led by *Sagittaria latifolia*, with 19.7% and 26.6% of the total cover for each year, respectively.

The Atchafalaya SR assessment unit consists of longstanding mainland fresh marsh sites. The SR sites were first surveyed in 2006, and it is theorized that the number of dominant invasive species present are indicative of disturbance conditions that would be expected after Hurricane Rita. From 2007-2015, the SR vegetation remained consistent, with the total percentages ranging from 70.0% to 86.8% cover. Approximately half of the average total cover consisted of the "other" class species. This is typical for fresh marsh, which has the greatest plant diversity of any marsh type (Lester et al. 2005). This period, which was dominated by the dominant species *Panicum hemitomon* and *Spartina patens*; the common species *Leersia hexandra* and *Spartina cynosuroides*; the rigorous species *Zizaniopsis miliacea*, *Nelumbo lutea*, and *Phragmites australis*; and the disturbance species *Bidens laevis* and *Vigna luteola*; rarely had a single species with cover values greater than 10%.

The vegetation survey data show that the communities differed greatly between the Atchafalaya assessment units. These differences were primarily due to differences in elevation (Curole and Babin 2010), which were estimated at 1.35 ft, 1.17 ft, and 2.15 ft (NAVD88) for Atchafalaya Project, PR, and SR sites, respectively (2010 LiDAR data, CPRA 2012). The vegetative communities also differed due to varying age of marsh across all Atchafalaya assessment units. The Project and SR sites are relatively young deltaic marsh compared to long-established SR mainland marsh. Additionally, increasing establishment and cover of aquatic vegetation, like *Nelumbo lutea*, are the results of the constructed channels distributing sediment and building additional wetland area adjacent to the restored islands.

3.1.3 Little Lake vegetation

Since the 1950s, the Little Lake study area has varied from intermediate to brackish marsh, with a shift to higher salinity species (*Spartina patens*, *Distichlis spicata*, and *Juncus roemerianus*) in recent decades (GOTECH Inc. 2003). The Little Lake CWPPRA project (BA-37) was constructed in 2007 with both created and nourished wetlands in a highly subsiding and degrading landscape. Figure 4 shows the average percent cover by species for all stations within assessment units by year for the Little Lake study

site. There were 126 unique plant species observed across all units and stations from 1999 to 2015.

The total cover for the first Little Lake Project survey, performed in 2008, was 77.0% and dominated by common and dominant wetland species. The dominant plants in 2008 consisted of *Spartina patens* (20.3% cover), *Spartina alterniflora* (14.4%), *Cyperus filicinus* (9.8%), and *Schoenoplectus americanus* (7.6%). These dominant species remained throughout the 2008 to 2015 period, with yearly or seasonal dominant occurrences of *Paspalum vaginatum*, *Distichlis spicata*, *Sacciolepis striata*, and the disturbance species *Amaranthus australis*, *Setaria parviflora*, and *Vigna luteola*. The percent cover for the "other" species ranged from 2.9% in 2008 to 25.8% in 2015.

The PR area consists of brackish marsh located northwest of the Little Lake Project area. The PR survey stations consisted of Gulf Intracoastal Waterway (GIWW) to Clovelly Hydrologic Restoration (BA-02) CWPPRA project sample sites. The PR area is in close proximity to the Little Lake Project area, is typical of marsh condition in the Barataria Basin, and has ample vegetation survey data. The BA-02 project phases, which were constructed in 1997 and 2000, were intended to provide wetland stability through hydrologic restoration and shoreline protection. Two years after the first phase of BA-02, the vegetation within PR sites was common and dominant communities, consisting of *Schoenoplectus* (Reichenb.) *Palla* (bulrush, 18.0 % cover), *Spartina patens* (15.3%), *Schoenoplectus robustus* (13.3%), and *Spartina alterniflora* (10.7%). After the second phase of BA-02, there were shifts in vegetation to communities that were dominated by *Spartina patens*, *Eleocharis cellulosa*, *Schoenoplectus americanus*, and *Ipomoea sagittata*, with intermittent and moderate coverage by *Kosteletzkya virginica*, *Juncus roemerianus*, and *Schoenoplectus pungens* (common threesquare). During the BA-02 post construction period, the total vegetation cover ranged from 55.9% to 87.1%, and the cover of the "other" class ranged from 12.9% to 34%.

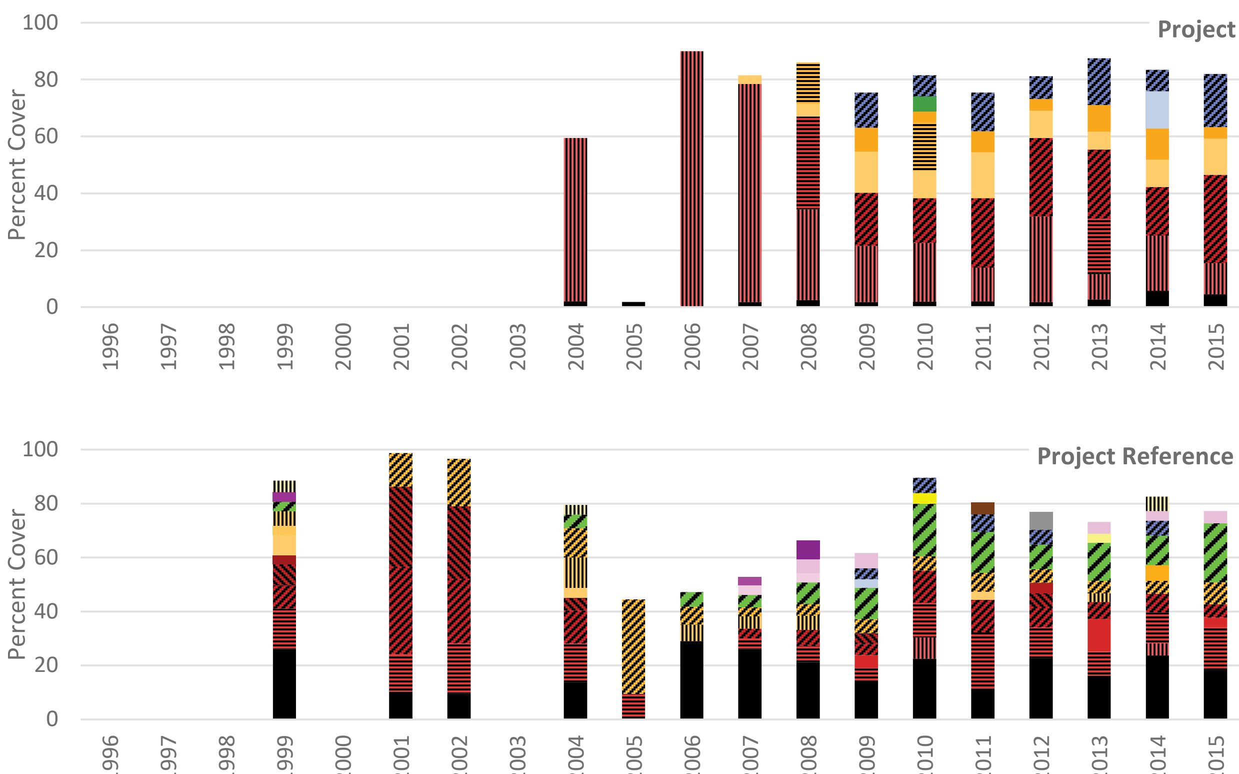
The SR area consisted of multiple CWPPRA survey sites BA-20, BA-23, and BA-39, as well as multiple CRMS stations. The vegetation surveys were conducted in the SR areas between 2006 and 2015 and show total average cover ranging from 74.4% to 87.6%. The general vegetative communities present at these sites are consistent with those at the PR sites, except the SR survey sites contained higher counts and cover of

disturbance species, and relatively higher percentages of cover from the "other" species.

The Little Lake Project sites were similar in total cover and dominant species to the PR and SR sites. However, the Project sites did contain lower percentages of cover from the "other" species, and typically had fewer disturbance species than both reference areas.

These vegetative surveys and community descriptions are typical for vegetation-based monitoring and assessments of restoration projects and performance. Plant species identification and cover values allow for the monitoring of project sites and for comparison to reference wetlands or other restoration projects. Shifts in vegetative species and/or cover are useful for identifying key disturbances, pulses and presses, and ultimately as indicators of wetland condition. However, additional metrics or indices would be helpful to complement interpreting and understanding shifts in vegetative communities and changes in percent cover.

Figure 2. Percent cover and CC values for species within the Sabine assessment units.



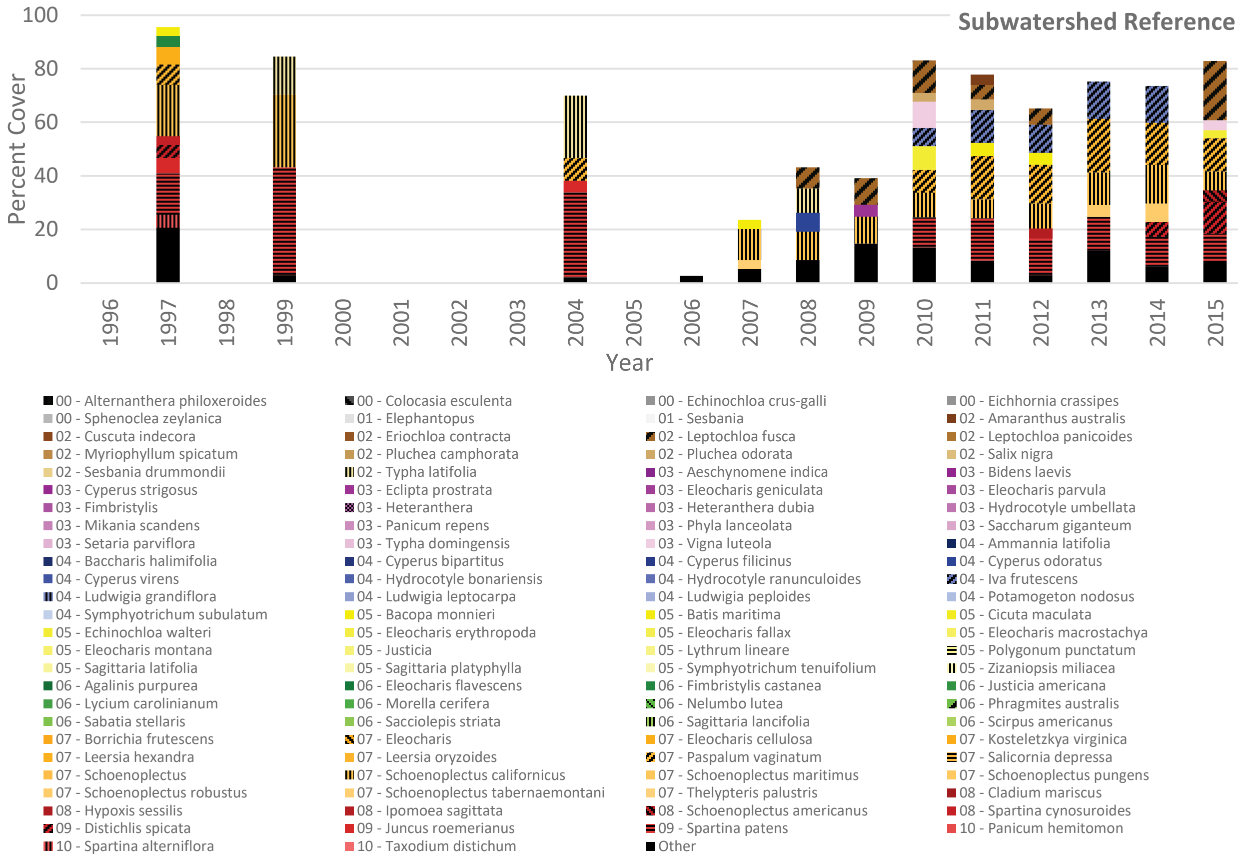
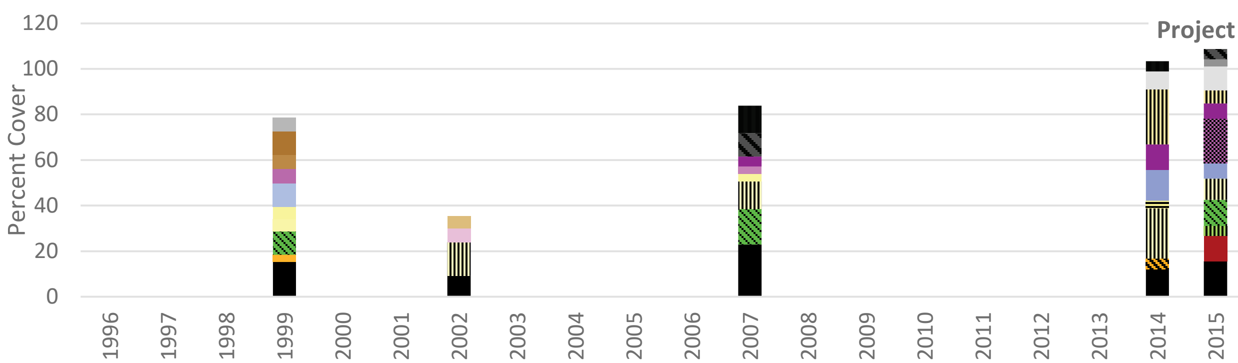
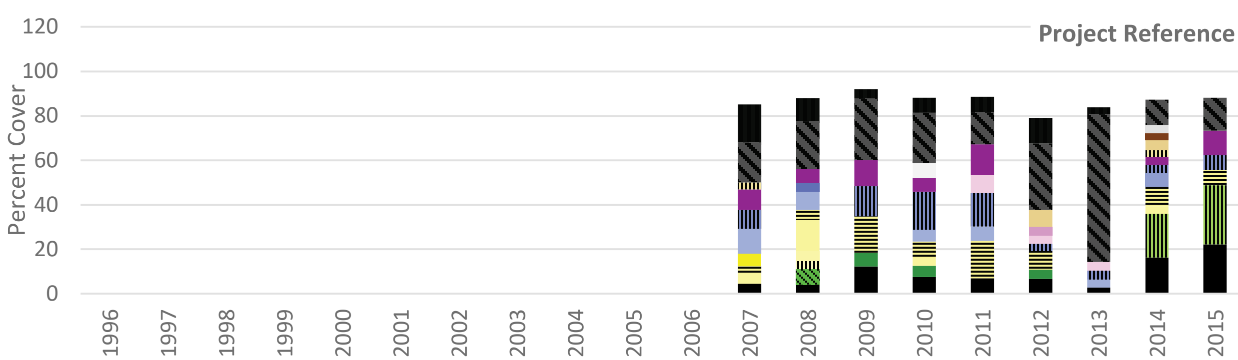


Figure 3. Percent cover and CC values for species within the Atchafalaya assessment units.





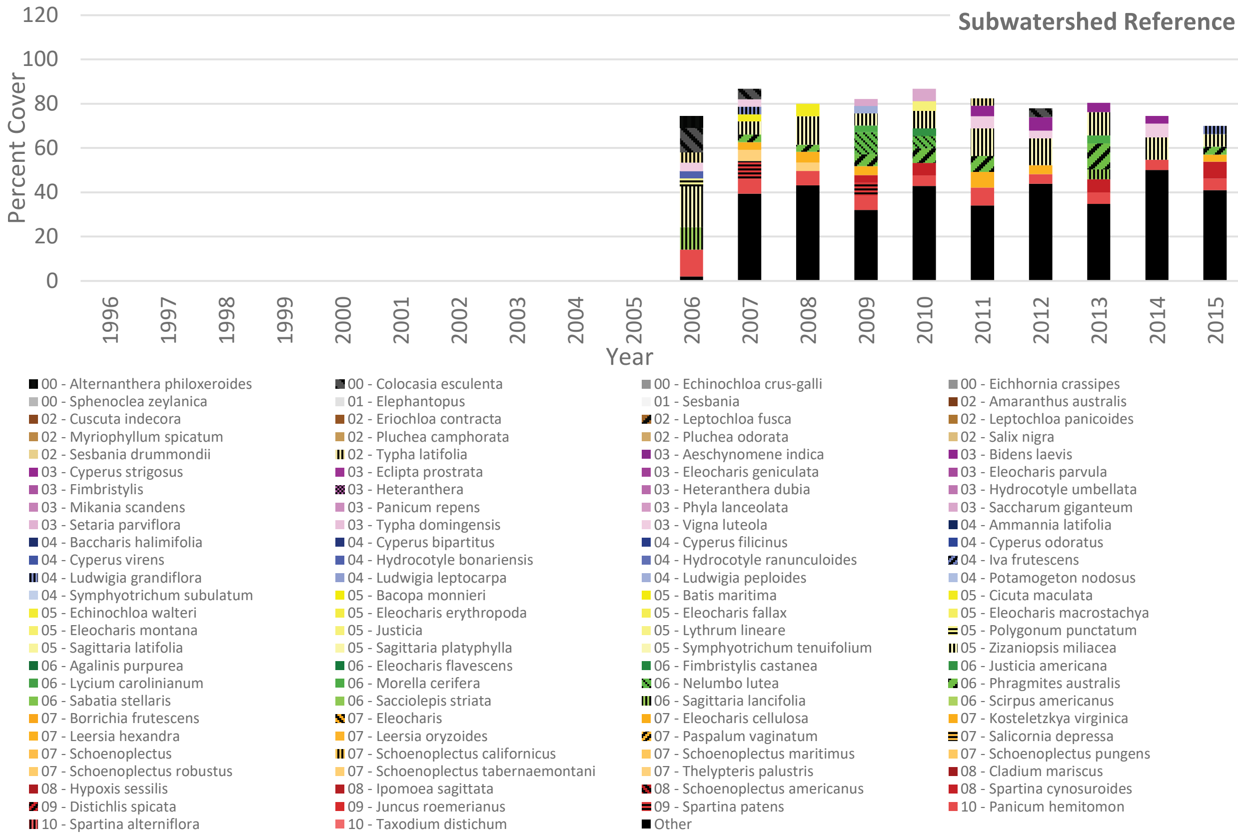
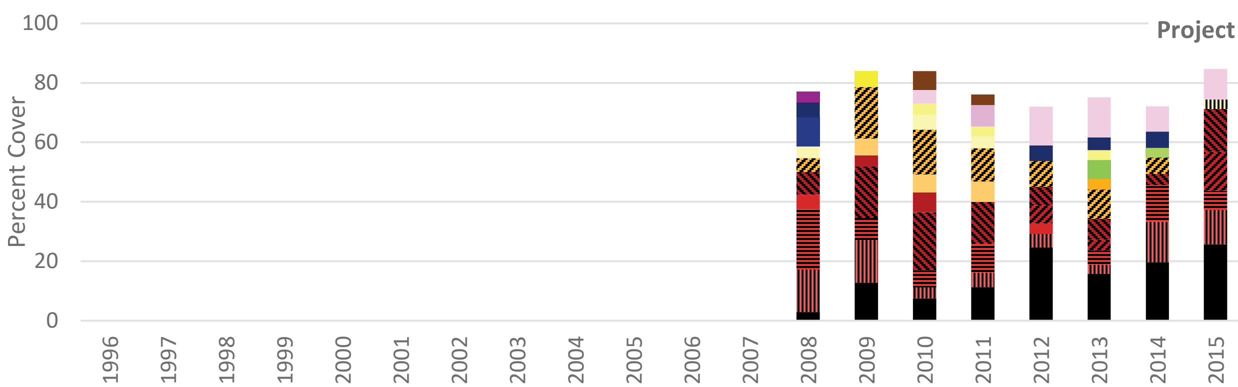
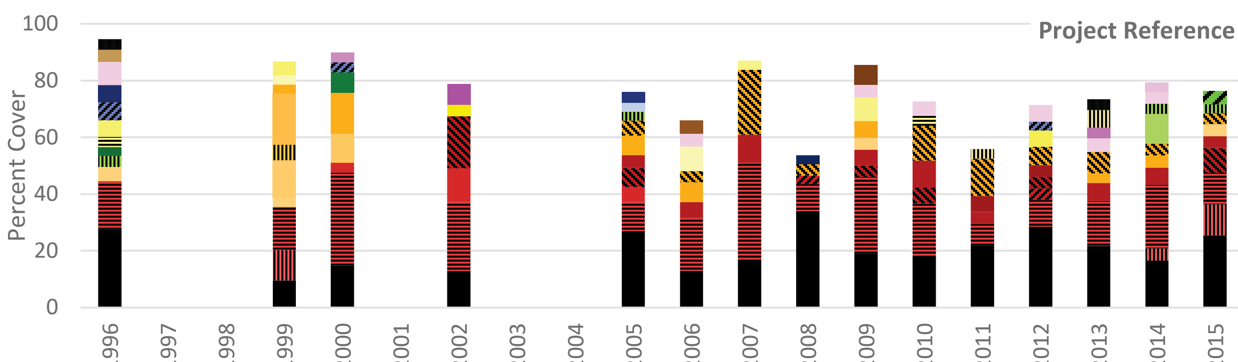
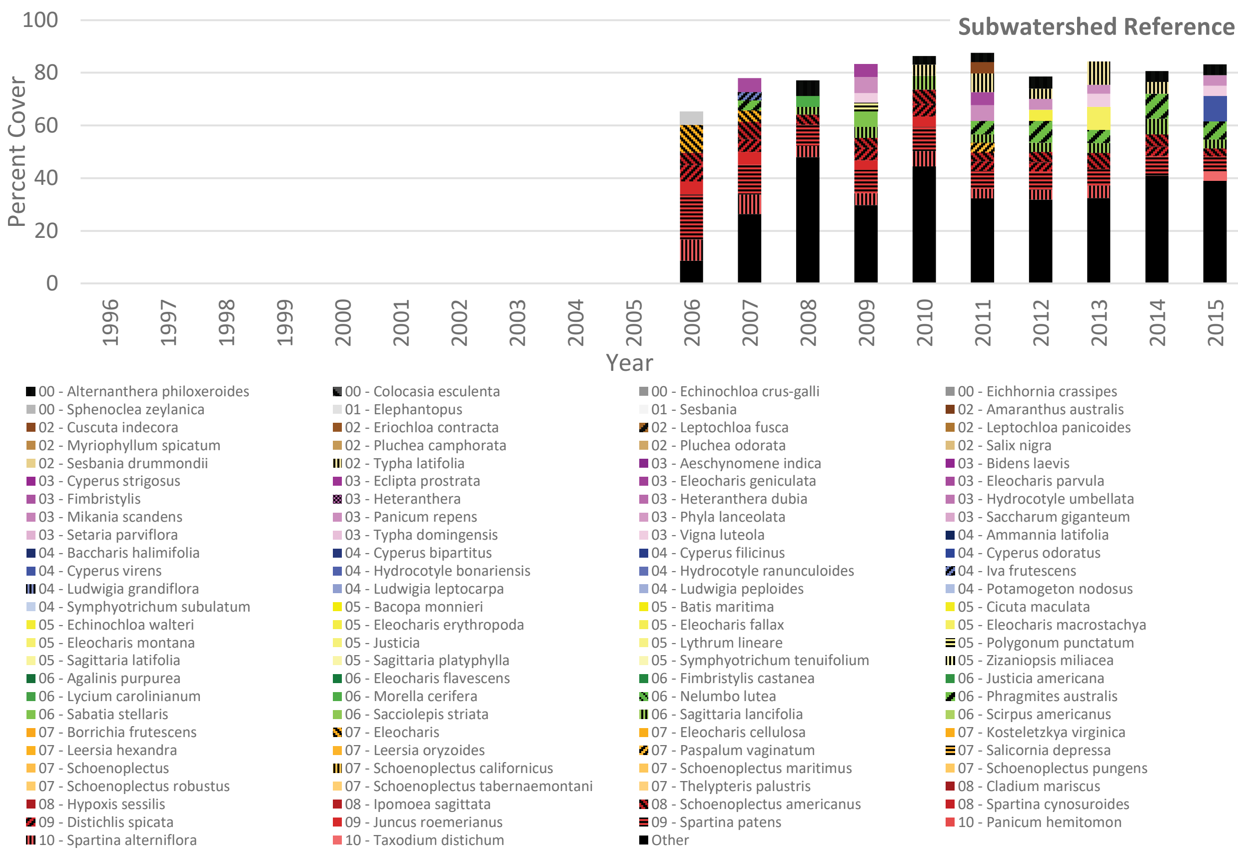


Figure 4. Percent cover and CC values for species within the Little Lake assessment units.





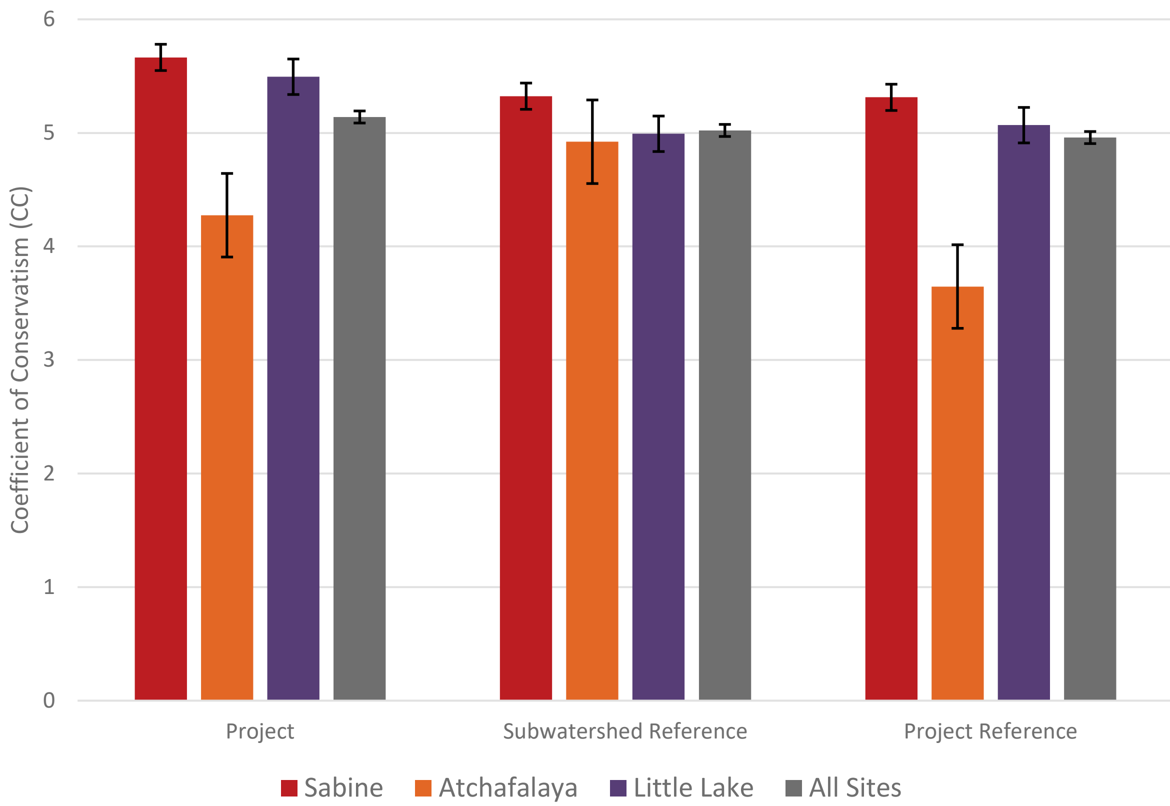


3.2 Coefficients of conservatism

The Coefficients of Conservatism (CC) is a value that indicates a plant's fidelity to specific habitat types and degree of ecological tolerance (Gianopulos 2014). CC values provide measures of wetland quality and are therefore useful indicators of wetland condition, and system pulses, presses, and disturbance events. Figure 5 illustrates the average Coefficient of Conservatism for all survey stations by study site assessment units. Figure 5 also shows the combined average CC values for all study sites (Sabine, Atchafalaya, and Little Lake combined), by assessment unit. The average CC values for the Project assessment units are 5.66, 4.27, 5.49, and 5.14 for the Sabine, Atchafalaya, Little Lake, and all study sites, respectively. The average CC values within the PR units were lower than the Project units but had similar trends across the study sites. The average CC values within the SR units were generally between the Project and PR values, except for the Atchafalaya study site, which registered its highest average CC value within the SR unit. This exception is likely due to the SR sites being located in long-established mainland marsh, where the Project and PR wetlands are in relatively recently constructed/established marsh in higher energy environments. These overall findings are expected since fresh marsh, like

those within the Atchafalaya study area, are more accommodating to a higher number of plant species, including invasive plants. Conversely, higher salinity levels in brackish and saline marshes, like those at Sabine and Little Lake, restrict the number of viable species and therefore are less prone to colonization by invasive and disturbance species.

Figure 5. Average CC for all survey stations within study site assessment units.



3.3 Floristic quality

3.3.1 Sabine FQI

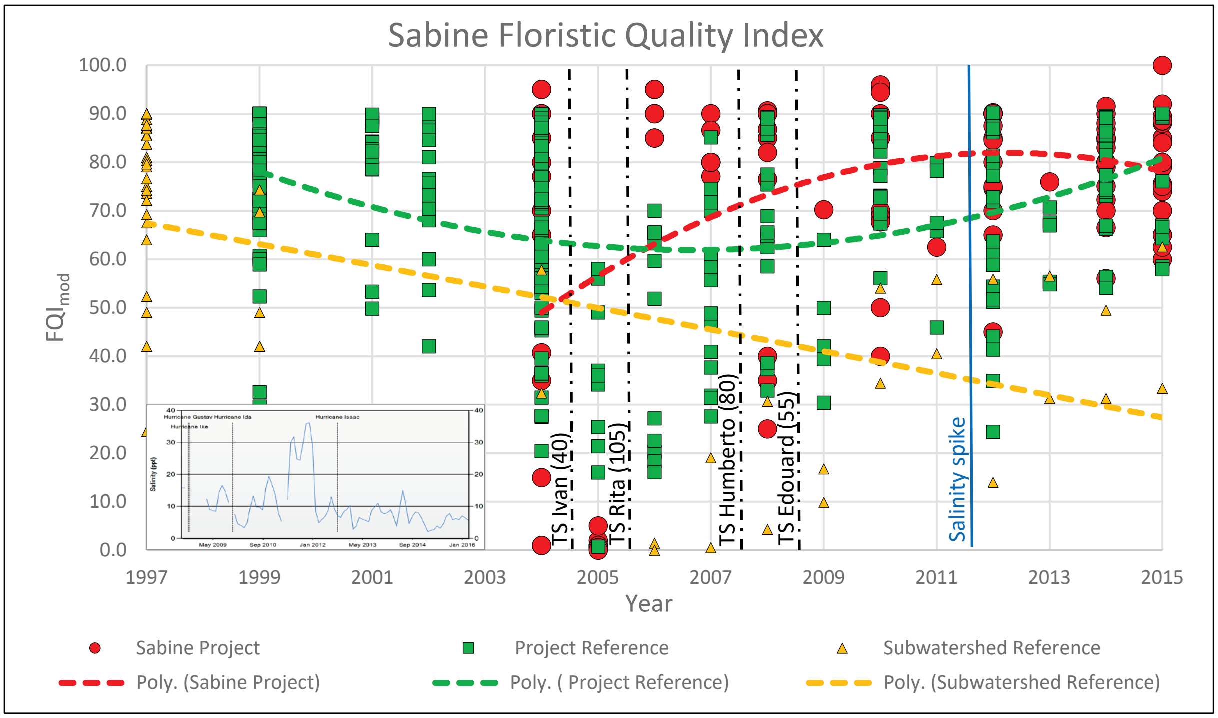
The FQI_{mod} scores were calculated for each survey site within the Sabine assessment units from 1997 to 2015 (Figure 6). The Project sites (red dots), consisting of Cycle 1 and Cycle 3, were first surveyed in 2003 (post construction of Cycle 1) and last surveyed in 2015. The PR sites (green squares) were surveyed from 1999 to 2015, and the SR sites (yellow triangles) were surveyed from 1997 to 2015. Trendlines (2nd order polynomial) within Figure 6 show the trends and trajectories of FQI_{mod} values across each assessment unit's period of analysis. The Subwatershed Reference unit data and trendline show a landscape with rapidly declining floristic quality. This is indicative of a system with degrading wetland

function and corroborates previous studies that have shown significant wetland area and function loss due to hurricanes, saltwater intrusion, increased water fluctuations, and tidal scouring (Barras 2005, LCWCRTF 2002, and Miller 2014). The Project Reference unit data and trendline show a landscape that was on a declining trajectory but stabilized in 2007 and subsequently has had an increasing FQI_{mod}. The long-term degeneration that has occurred in this area is evident from 1999-2004 (Figure 6); however, a CWPPRA project aimed at restoring hydrologic connectivity was completed in the PR unit in 2001, and its impact can be observed in the increasing FQI_{mod} scores from 2007 to 2015. The Project unit data and trendline show a landscape with early increasing floristic quality; however, the FQI scores have experienced a slight decreasing trend since 2012, which may be attributable to increased salinity levels and hurricane impacts. Though the PR unit is proximal to the Project unit, the effects of salinity may vary due to containment dikes and hydrologic alterations. The inset chart in Figure 6 shows the average salinity values measured at the Project CRMS station. The elevated salinity (upwards of 35 parts per thousand (ppt)) at the end of 2011 and effects from Hurricane Isaac (2012) may have impacted vegetation and FQI_{mod} scores between 2012 and 2015. The Project unit FQI_{mod} data and trends are indicative of the rapid colonization and vegetative growth that are common in newly constructed wetlands. The Project unit average FQI_{mod} score from 2010 to 2015 was approximately 80. This coincides with the ideal range for Chenier Plain brackish marsh that was reported by Cretini et al. (2012) (Table 3). Since construction, the Project sites have primarily had higher floristic quality than both of the reference units.

Table 3. Preliminary ideal range for vegetation indices in Louisiana's principal geological settings. (Cretini et al. 2011)

Geological setting	Habitat type	FQI_{mod}
Inactive deltaic plain	Fresh marsh	>80
	Intermediate marsh	>80
	Brackish marsh	>80
	Saline marsh	>80
Active deltaic plain	Fresh marsh	>70
	Intermediate marsh	>70
Chenier plain	Fresh marsh	>80
	Intermediate marsh	>80
	Brackish marsh	>80
	Saline marsh	>80

Figure 6. Floristic Quality Index (FQImod) scores for all survey stations within the Sabine assessment units by year. Vertical lines and inset chart provide tropical storm (TS) activity (wind speed miles per hour) and salinity data, respectively.

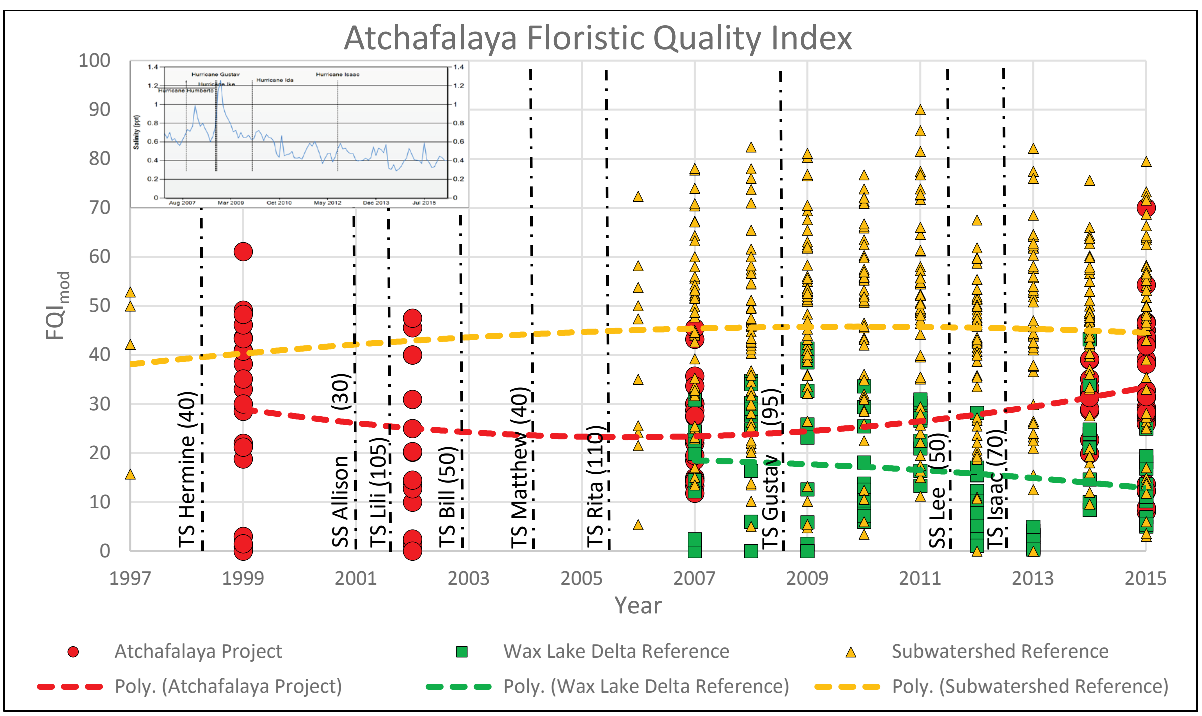


3.3.2 Atchafalaya FQI

The FQImod scores were calculated for each survey site within the Atchafalaya assessment units from 1997 to 2015 (Figure 7). The Project sites, represented by red dots, were first surveyed in 1999 (post construction of CWPPRA AT-03) and were last surveyed in 2015. The PR sites (green squares) were surveyed from 2007 to 2015, and the SR sites (yellow triangles) were surveyed from 1997 to 2015. Trendlines (2nd order polynomials) within Figure 7 show the trends and trajectories of FQImod values across each assessment unit's period of analysis. The Subwatershed Reference unit data show a slight positive trend in FQImod from 1997 to 2010, then a slight decreasing trend through 2015. The range in mean SR FQImod across the period of analysis is from approximately 39 to 45. This is indicative of a system with highly stable wetlands and ecosystem function and corroborates previous studies that have shown the wetlands in close proximity to the lower Atchafalaya River to be some of the most stable and productive in coastal Louisiana (CWPPRA 2016). The Project Reference unit data show a landscape with the lowest FQImod scores of all Atchafalaya units. The trendline for the PR unit shows moderately declining FQImod scores from 2007 to 2015, and is indicative of early successional communities in a slowly pro-grading delta. The Project area wetlands were

constructed in 1998, and by the first vegetation survey in 1999, the Project sites had a mean FQI_{mod} score of approximately 30. This score is lower than the ideal range for fresh marsh in Louisiana's active Deltaic Plain, and lower than those at the mainland SR sites; however, it is reasonable in a high-energy riverine setting. The Project FQI_{mod} scores show a moderately declining trend from 1999 to 2006. These conditions were probably influenced by Hurricanes Lili and Rita in 2002 and 2005, respectively. The inset chart in Figure 7 shows one spike in salinity as a result of Rita's storm surge. However, the magnitude and duration of the spike is relatively small and no salinity impacts are observed in subsequent FQI_{mod} data. From 2007 to 2015, the Project FQI_{mod} scores show moderately increasing trends, and at current trajectories are outperforming the PR sites and may soon approach mainland SR site FQI_{mod} scores. Some of the trendline breakpoints in Figure 7 occur around 2011. These are possible effects of the historic high Mississippi River flood that occurred in spring 2011, which could have introduced additional flooding stress to the PR and SR vegetation communities (Carle et al. 2013).

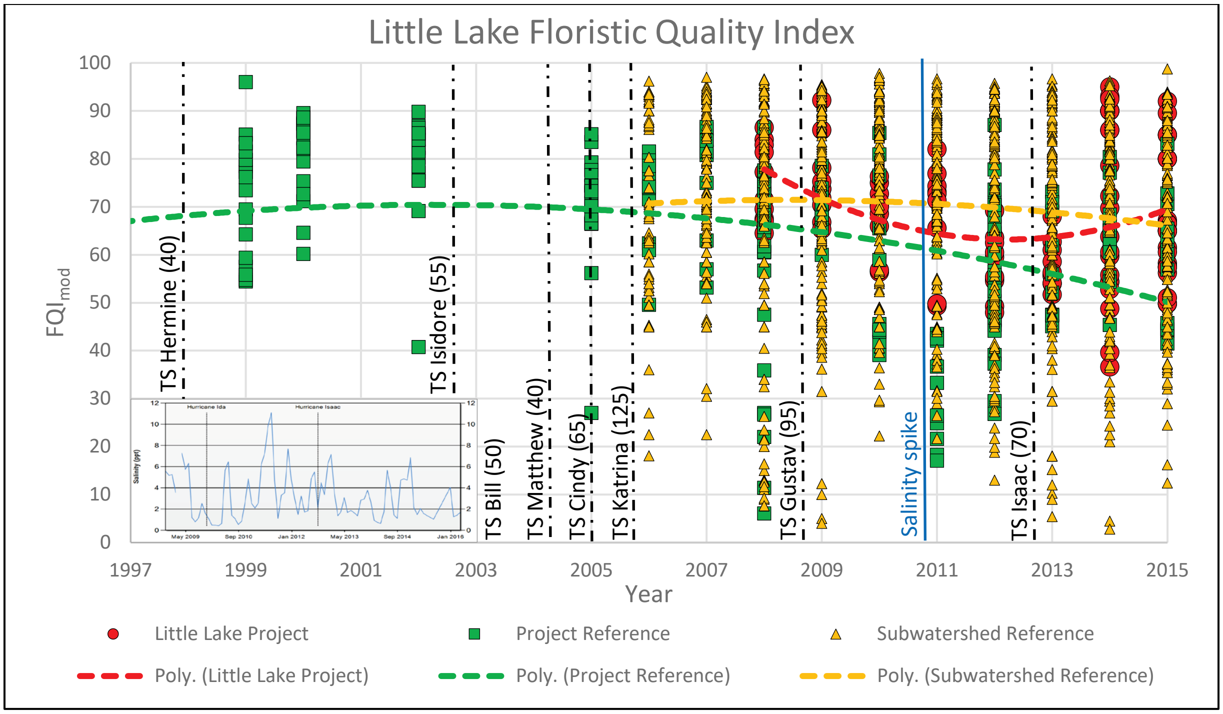
Figure 7. Floristic Quality Index (FQI_{mod}) scores for all survey stations within the Atchafalaya assessment units by year. Vertical lines and inset chart provide tropical storm (TS) activity (wind speed miles per hour) and salinity data, respectively.



3.3.3 Little Lake FQI

The FQI_{mod} scores were calculated for each survey site within the Little Lake assessment units from 1999 to 2015 (Figure 8). The Project sites, represented by red dots, were first surveyed in 2008 (post construction of CWPPRA BA-37) and were last surveyed in 2015. The PR sites (green squares) were surveyed from 1999 to 2015, and the SR sites (yellow triangles) were surveyed from 2006 to 2015. Similar to Figures 6 and 7, Figure 8 shows the trendlines and trajectories of FQI_{mod} values for each assessment unit. The Subwatershed Reference unit data show a consistent FQI_{mod} score of approximately 70 from 2006 to 2011, then a slight decreasing trend through 2015. These scores are below the ideal range of 80 for brackish marsh in Louisiana's inactive Deltaic Plain (Table 3). The recent decreasing SR FQI_{mod} scores are possibly the result of Hurricane Isaac (2012) impacts. The SR unit is one of substantial wetland deterioration, primarily as a result of saltwater intrusion and rapid subsidence; nevertheless, multiple hydrologic restoration projects (Naomi Outfall Management BA-03c and Jonathan Davis Wetland Restoration BA-20) have been constructed in an attempt to help stabilize the area. The Project Reference unit data show an average FQI_{mod} score of 70 in 2002, and a consistent FQI_{mod} decline to approximately 50 by 2015. The vegetation survey data in Figure 4 show that during this period, the PR stations transitioned to higher CC communities (common and dominant vegetation), so the declining FQI_{mod} scores indicate a landscape that is transitioning from higher cover values to one of significantly less cover. The Project area wetlands were constructed in 2007, and by the first vegetation survey in 2008, the Project sites had a mean FQI_{mod} score of approximately 78. This score is near the ideal range for brackish marsh in Louisiana's inactive Deltaic Plain (Cretini et al. 2011), and higher than any mean FQI_{mod} observed in the PR or SR units. The Project exhibited declining mean FQI_{mod} scores from 2008 to 2012, reaching a minimum of approximately 64. These conditions were probably influenced by Hurricanes Gustav and Isaac in 2008 and 2012, respectively. The inset chart in Figure 8 also shows monthly average salinity from the Project CRMS station. There was one moderately high salinity spike that was observed across this period of record. The 11.1 ppt spike occurred in 2011, and may have contributed to lowering FQI_{mod} values. From 2012 to 2015, the Project FQI_{mod} scores show moderately increasing trends, having intersected the SR trajectory in 2014, and reaching an FQI_{mod} score of approximately 70 in 2015. These increases in FQI_{mod} scores represent a Project landscape that is effectively recovering from stressors (i.e., hurricane impacts) and has higher recent wetland function than the PR and SR wetlands.

Figure 8. Floristic Quality Index (FQImod) scores for all survey stations within the Little Lake assessment units by year. Vertical lines and inset chart provide tropical storm (TS) activity (wind speed miles per hour) and salinity data, respectively.



3.3.4 FQI summary

Table 4 provides FQI_{mod} summary information for all Sabine study site assessment units by year. The FQI_{mod} mean values are reported with a ±1 standard error (SE) of the mean. To compare FQI_{mod}, the 95% confidence interval of the sample means were estimated using two times the standard error (m ± 2SE) (Matthews 2016). Also provided are the differences in means between Project and PR and SR units. The difference values are color ramped, with green representing positive values (darker greens are higher values) and red representing negative values (darker reds are lower values). With regard to floristic quality, the overall Sabine averages show that the Project sites performed better than the PR and SR sites, 69.4 versus 65.0 and 37.0, respectively. The average difference in FQI_{mod} values between the Sabine Project and SR units for paired years was 44.1. The differences in Project and SR FQI_{mod} values, represented largely by dark green colors, indicate landscapes at opposite ends of the wetland condition spectrum. The restored Project unit is experiencing robust vegetative growth, while the SR unit is continuing along a trend of wetland degradation. Excluding a few years (hurricane and salinity impacts), the average FQI_{mod} by year for the Project unit was above or near the preliminary ideal range reported by Cretini et al. (2011), where the average

FQI_{mod} within the SR unit experienced only one of fourteen years at or above the ideal range, with the majority of years significantly below the ideal range. The Project and PR units were more similar in overall mean FQI_{mod}. Comparing the confidence intervals of the twelve paired Project and PR unit means, six were significantly different (five with higher Project values) and six were not significantly different. The years (2004, 2005, 2010, and 2011) where the PR means were higher (regardless of significance) were in periods where hurricane and salinity impacts affected Project FQI_{mod} values. It is theorized that the differences in these impacts were largely driven by landscape maturity and stability, and variations in hydrology (e.g., impoundments due to containment dikes). Generally, the Project unit outperformed the PR unit, and if hurricane-impacted years are excluded, the Project unit had an overall FQI_{mod} average that was ten points higher than the PR unit.

Table 4. Mean FQI_{mod} by year for each assessment unit within the Sabine study sites. Differences in FQI between Project (P) and Subwatershed Reference (SR) and Project Reference (PR) are provided and color coded (dark green represents difference values near 100 and dark red represents values near -100).

Year	Sabine (Average FQImod)				
	SR	Difference between P and SR	P	Difference between P and PR	PR
1997	80.2 ± 2.1				
1998					
1999	55.4 ± 6.9				75.9 ± 2.1
2000					
2001					79.9 ± 3.0
2002					76.5 ± 3.4
2003					
2004	45.1 ± 12.7	14.8	59.9 ± 9.3	-6.2	66.1 ± 2.0
2005			1.4 ± 0.6	-31.9	33.3 ± 5.7
2006	0.7 ± 0.7	89.3	90.0 ± 1.5	44.6	45.4 ± 6.4
2007	9.8 ± 9.3	72.1	81.9 ± 1.7	28.7	53.2 ± 4.5
2008	17.5 ± 13.2	55.4	72.9 ± 7.1	5.0	67.9 ± 5.0
2009	13.2 ± 3.5	56.9	70.1 ± 0.0	25.0	45.1 ± 5.6
2010	44.2 ± 9.8	33.9	78.1 ± 5.2	-3.7	81.8 ± 1.8
2011	48.1 ± 7.6	14.3	62.4 ± 0.0	-5.0	67.4 ± 6.1
2012	34.9 ± 21.0	46.6	81.5 ± 3.0	14.3	67.2 ± 4.1
2013	43.9 ± 12.7	32.0	75.9 ± 0.0	12.9	63.0 ± 3.3
2014	40.3 ± 9.1	39.2	79.5 ± 2.2	0.9	78.6 ± 2.2
2015	47.9 ± 14.6	31.1	79.0 ± 1.9	5.8	73.2 ± 4.4
Average	**37.0 ± 6.0**	**44.1**	**69.4 ± 6.6**	**7.5**	**65.0 ± 3.8**

The mean ± the standard error is given for the FQImod variable.

The overall FQI_{mod} averages for the Atchafalaya site are 44.5, 28.3, and 16.2, for the SR, Project, and PR units, respectively (Table 5). The yearly FQI_{mod} averages for the SR unit ranged from 39.3 to 49.2. These FQI_{mod} values remained relatively steady over the 18-year period of analysis, but were well below the ideal range (>70) that was established by Cretini et al. (2011) for an active deltaic plain. However, Cretini et al. (2011) reported that their preliminary ranges may require future adjustments. Since the SR sites are in some of the most productive and vigorous wetlands in

South Louisiana, it may be that a more appropriate ideal range has a minima FQI_{mod} near 50. The overall difference in average between Atchafalaya Project and SR unit FQI_{mod} was -15.1. Comparing 95% confidence intervals ($m \pm 2SE$), the SR unit means were significantly higher than the Project FQI_{mod} means in all four paired years. These differences were primarily due to the mature condition of the established mainland SR wetlands compared to the immature and early successional wetlands in the constructed Project unit. The PR unit is also immature and in early successional stages, but is pro-grading and accreting through natural processes via the Wax Lake Outlet. The 13.3 difference in overall average FQI_{mod} between the Project and PR units may be related to the differences in natural and construction processes and subsequent differences in elevation. Comparing 95% confidence intervals ($m \pm 2SE$), the Project unit means were significantly higher than the PR FQI_{mod} means in most of the paired years (slight overlap in confidence intervals in 2014). Generally, the yearly FQI_{mod} averages for all units remained relatively consistent (less than or equal to ±8 FQI_{mod} of the overall average), except for 2013, where the landscape was still exhibiting impacts from Hurricane Isaac. The SR mainland unit outperformed the Project and PR units, but those differences are primarily related to elevation and wetland maturity.

The overall FQI_{mod} averages for Little Lake were similar for all assessment units (Table 6). The Project unit had a slightly higher overall FQI_{mod} score (67.4) than the SR (66.9) or PR (64.5) units. With regard to yearly FQI_{mod} means, the Little Lake Project site had slightly higher scores than the SR site, though based on the 95% confidence intervals, only one out of eight paired years were significantly different. These scores, ranging from 57.8 to 75.3 for the Project unit, and 62.4 to 74.5 for the SR, are lower than the ideal range reported by Cretini et al. (2011), but are probably high for a rapidly subsiding landscape experiencing recent hurricane impacts and frequent fluctuations in salinity. Though the overall average FQI_{mod} scores in Project and PR units were also similar, there was a wide range of within-year differences. Seven of eight paired years show the mean FQI_{mod} values were higher in the Little Lake Project unit than in the PR, though based on the 95% confidence intervals, only one year was significantly higher. The differences ranged from a low of -0.7 in 2013 to a high of 35.8 in 2011. The larger differences in paired FQI_{mod} values between Project and PR units were observed in 2008 and 2011. These differences are probably related to Hurricane Gustav's impact to the region in 2008 and the higher salinity event that occurred in 2011 (possible effects of Tropical Storm Arlene), and the protection that containment dikes provided to the Project unit.

Table 5. Mean FQI_{mod} by year for each assessment unit within the Atchafalaya study sites. Differences in FQI between Project (P) and Subwatershed Reference (SR) and Project Reference (PR) are provided and color coded (dark green represents difference values near 100 and dark red represents values near -100).

Year	Atchafalaya (Average FQI_{mod})				
	SR	Difference between P and SR	P	Difference between P and PR	PR
1997	40.2 ± 8.5				
1998					
1999			30.3 ± 4.0		
2000					
2001					
2002			21.6 ± 4.1		
2003					
2004					
2005					
2006	39.3 ± 6.4				
2007	45.3 ± 2.4	-20.1	25.2 ± 2.4	11.1	14.1 ± 3.3
2008	42.9 ± 2.6				23.1 ± 3.7
2009	49.2 ± 2.5				18.1 ± 5.1
2010	47.8 ± 2.6				16.4 ± 3.1
2011	48.4 ± 2.9				24.5 ± 1.9
2012	40.5 ± 2.1				11.5 ± 2.6
2013	45.9 ± 2.7				2.4 ± 0.5
2014	43.9 ± 2.1	-12.8	31.1 ± 1.8	8.8	22.3 ± 3.3
2015	45.6 ± 2.6	-12.3	33.3 ± 2.8	20.1	13.2 ± 2.1
Average	**44.5 ± 1.0**	**-15.1**	**28.3 ± 2.1**	**13.3**	**16.2 ± 2.3**

The mean ± the standard error is given for the FQI_{mod} variable.

Table 6. Mean FQImod by year for each assessment unit within the Little Lake study sites. Differences in FQI between Project (P) and Subwatershed Reference (SR) and Project Reference (PR) are provided and color coded (dark green represents difference values near 100 and dark red represents values near -100).

Year	Little Lake (Average FQI_{mod})				
	SR	Difference between P and	P	Difference between P and PR	PR
1997					
1998					
1999					71.4 ± 3.0
2000					80.7 ± 2.2
2001					
2002					79.2 ± 2.7
2003					
2004					
2005					70.0 ± 3.2
2006	66.9 ± 1.9				70.9 ± 3.2
2007	74.5 ± 1.6				75.1 ± 4.0
2008	68.7 ± 2.1	6.5	75.2 ± 2.6	16.6	58.6 ± 4.3
2009	68.2 ± 1.5	7.2	75.3 ± 2.6	5.4	70.0 ± 1.6
2010	64.9 ± 2.1	3.4	68.3 ± 2.2	10.1	58.2 ± 5.6
2011	65.2 ± 1.8	1.3	66.5 ± 3.9	35.8	30.7 ± 3.3
2012	64.3 ± 1.7	-6.6	57.8 ± 2.1	1.4	56.4 ± 2.8
2013	66.6 ± 1.9	-8.8	57.8 ± 1.5	-0.7	58.5 ± 3.3
2014	62.4 ± 1.9	8.5	70.9 ± 4.0	6.7	64.2 ± 2.6
2015	67.2 ± 1.7	0.5	67.7 ± 2.8	8.6	59.1 ± 3.8
Average	**66.9 ± 1.0**	**1.5**	**67.4 ± 2.4**	**10.5**	**64.5 ± 3.4**

The mean ± the standard error is given for the FQImod variable.

4 Conclusion

Vegetation provides one of the best indicators for assessing the condition and performance of wetlands (Fennessy et al. 2002). However, using standard approaches with vegetation classification and cover data to assess wetland condition and restoration performance can be demanding, especially with long periods of analyses and large quantities of data. Though these standard measures provide assessments of vegetation species presence and abundance (percentage of cover), using these measures to compare the condition of one wetland area to another would benefit from complementary methods more aligned to assess quality. Therefore, the purpose of this study was to evaluate the utility of an FQI_{mod} for assessing the performance and resilience of restored wetlands by comparing those to reference wetlands.

Though the standard FQI approach was originally established to assess disturbance impacts on naturally occurring vegetation communities, it is theoretically suited for assessing the establishment and development of created wetlands and comparing those to wetlands at varying scales and chronosequence. The results of this study show that the FQI_{mod} data successfully reflected large disturbance events, namely hurricanes and major fluxes in salinity. The FQI_{mod} assessments also successfully identified differences due to wetland elevation, age, and hydrology. The modified FQI also provides measures of restoration type (e.g., planted versus not planted, marsh creation versus nourishment), chronosequence (condition and stability over time), and trajectory (i.e., intersecting trend lines when restored marsh FQI approaches reference marsh condition).

Though the FQI_{mod} provides a useful complementary monitoring tool to use with standard vegetation assessments, there remain limitations and knowledge gaps. FQI_{mod} data are discretely sampled data that require time and labor-intensive field work. Additionally, CC values have not been developed for all states or regions within the United States. FQI_{mod} alone will not describe every aspect of wetland condition, so it must be complemented by indices describing hydrologic and other functional processes to develop a more complete assessment of wetland condition. Future work should include methods that provide continuous spatial data (vegetation quality and productivity), which would allow for more representative FQI_{mod} assessments over larger landscape areas. These modifications could be incorporated into higher level assessment systems

(i.e., Level 3 - intensive site assessments) if more comprehensive evaluations of wetland form and function are required (DeKeyser et al. 2003).

Overall, FQI_{mod} provides a rapid and effective system for spatially and temporally assessing wetland condition and performance. Combining an FQI_{mod} with additional measures of wetland function (e.g., hydrology, soils, and elevation) can ultimately assist in future wetland restoration planning and adaptive management.

References

Andreas, B. K., J. J. Mack, and J. S. McCormac. 2004. Floristic Quality Assessment Index (FQAI) for vascular plants and mosses for the State of Ohio. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, Ohio.

Barras, J. A. 2005. Land area changes in coastal Louisiana after Hurricanes Katrina and Rita. Science and the storms: the USGS response to the hurricanes of 2005.

Bourdaghs, M., C. A. Johnston, and R. R. Regal. 2006. Properties and Performance of the Floristic Quality Index in Great Lakes Coastal Wetlands. *Wetlands* 26(3): 718-735.

Brown, Cunningham, & Gannuch Inc. 1998. Engineering Closure Report Big Island Mining (XAT-7) and Atchafalaya Sediment Delivery (PAT-2) As-Built Construction Phase. Prepared for State of Louisiana Department of Natural Resources and National Marine Fisheries Service DNR Contract No. 25085-95-04.

Carle, M. V. 2013. Spatial structure and dynamics of the plant communities in a prograding river delta: Wax Lake Delta, Atchafalaya Bay, Louisiana. PhD diss., LSU.

Carle, M. V., C. E. Sasser, and H. H. Roberts. 2013. Accretion and vegetation community change in the Wax Lake Delta following the historic 2011 Mississippi River flood. *Journal of Coastal Research* 313:569-587.

Chamberlain, S. J. and H. M. Ingram. 2012. Developing coefficients of conservatism to advance floristic quality assessment in the Mid-Atlantic region. *Journal of the Torrey Botanical Society* 139(4): 416-427.

Coastal Protection and Restoration Authority (CPRA) of Louisiana. 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority of Louisiana. Baton Rouge, LA.

Coastal Protection and Restoration Authority (CPRA) of Louisiana. 2016. Coastwide Reference Monitoring System-Wetlands Monitoring Data. Retrieved from Coastal Information Management System (CIMS) database. http://cims.coastal.louisiana.gov. Accessed 27 February 2016.

Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). 2016. The Atchafalaya Basin. https://lacoast.gov/new/About/Basin_data/at/Default.aspx. Accessed May 27, 2016.

Cohen, M. J., S. Carstenn, and C. R. Lane. 2004. Floristic Quality Indices for Biotic Assessment of Depressional Marsh Condition in Florida. *Ecol. Appl.*, 14(3): 784–794.

Couvillion, B. R., J. A. Barras, G. D. Steyer, W. Sleavin, M. Fischer, H. Beck, N. Trahan, B. Griffin, and D. Heckman. 2011. Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, 12 p. pamphlet.

Cretini, K. F., J. M. Visser, K. W. Krauss, and G. D. Steyer. 2011. CRMS vegetation analytical team framework—Methods for collection, development, and use of vegetation response variables: U.S. Geological Survey Open-File Report 2011-1097.

Cretini, K. F., J. M. Visser, K. W. Krauss, and G. D. Steyer. 2012. Development and use of a floristic quality index for coastal Louisiana marshes. *Environmental monitoring and assessment* 184(4): 2389-2403.

Curole, G. P. 2003. Monitoring Plan for Big Island Mining (AT-03), Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Lafayette, Louisiana.

Curole, G. P. and B. J. Babin. 2010. 2010 Operations, Maintenance, and Monitoring Report for Big Island Mining (AT-03), Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Thibodaux, Louisiana.

Dahl, T. E. 2010. Status and Trends of Wetlands in the Conterminous United States 2004 to 2009. Washington, DC: U.S. Fish and Wildlife Service.

Dahl, T. E. and G. J. Allord. 1996. Technical Aspects of Wetlands History of Wetlands in the Conterminous United States. National Water Summary on Wetlands Resources. United States Geological Survey Water Supply Paper 2425.

DeKeyser, E. S., D. R. Kirby, and M. J. Ell. 2003. An index of plant community integrity: development of the methodology for assessing prairie wetland plant communities. *Ecological Indicators* 3(2): 119-133.

Ervin, G. N., B. D. Herman, J. T. Bried, and D. C. Holly. 2006. Evaluating Non-Native Species and Wetland Indicator Status as Components of Wetlands Floristic Assessment. *Wetlands* 26(4): 1114-1129.

Fennessy, S., M. Gernes, J. Mack, and D. H. Wardrop. 2002. *Methods for Evaluating Wetland Condition: Using Vegetation to Assess Environmental Conditions in Wetlands*. U.S. Environmental Protection Agency, Office of Water, Washington, DC, USA. EPA 822-R-01-007j.

Folse, T. M., L. A. Sharp, J. L. West, M. K. Hymel, J. P. Troutman, T. E. McGinnis, D. Weifenbach, W. M. Boshart, L. B. Rodrigue, D. C. Richardi, W. B. Wood, and C. M. Miller. 2014. A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-Wetlands: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Baton Rouge, LA: Louisiana Coastal Protection and Restoration Authority.

Gianopulos, K. 2014. Coefficient of Conservatism Database Development for Wetland Plants Occurring in the Southeast United States. North Carolina Dept. of Environment & Natural Resources, Division of Water Resources: Wetlands Branch. Report to the EPA, Region 4.

GOTECH Inc. 2003. Environmental Assessment of Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake CWPPRA Project BA-37. Prepared for the United States Department of Commerce National Oceanic and Atmosphere Administration National Marine Fisheries Service, Silver Spring, MD.

Herman, B. D., J. D. Madsen, and G. N. Ervin. 2006. Development of coefficients of conservatism for wetland vascular flora of north and central Mississippi. Geo Resources Institute Report, 4001.

Johnson, W. B., C. E. Sasser, and J. G. Gosselink. 1985. Succession of vegetation in an evolving river delta, Atchafalaya Bay, Louisiana. *Journal of Ecology* 73: 973-986.

Karr, J. R., and E. W. Chu. 1997. *Biological monitoring and assessment: Using multimetric indexes effectively*. EPA/235/R97/001. Seattle, Washington: University of Washington.

Lester, G. D., S. G. Sorensen, P. L. Faulkner, C. S. Reid, and I. E. Maxit. 2005. Louisiana Comprehensive Wildlife Conservation Strategy. Louisiana Department of Wildlife and Fisheries. Baton Rouge.

Little, A. 2013. Sampling and Analyzing Wetland Vegetation. In *Wetland Techniques,* 273-324. Springer Netherlands.

Louisiana Coastal Wetlands Conservation and Restoration Task Force (LCWCRTF). 2002. Big Island Mining (AT-03).

Louisiana Coastal Wetlands Conservation and Restoration Task Force (LCWCRTF). 2015a. The 2015 Evaluation Report to the U.S. Congress on the Effectiveness of Coastal Wetlands Planning, Protection and Restoration Act Projects.

Louisiana Coastal Wetlands Conservation and Restoration Task Force (LCWCRTF). 2015b. Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37).

Louisiana Office of Coastal Protection and Restoration. 2009. Operation, Maintenance, and Rehabilitation Plan Little Lake Shoreline Protection / Dedicated Dredging Project BA-37. Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Lafayette, Louisiana. 194pp.

Mack, J. J. 2007. Developing a wetland IBI with statewide application after multiple testing iterations. *Ecological Indicators* 7: 864–881.

Matthews, J. N. S. 2016. Standard Errors and Confidence Intervals. School of Mathematics and Statistics, University of Newcastle. http://www.mas.ncl.ac.uk/~njnsm/medfac/docs/se&ci.pdf. Accessed May 16,2016.

Matthews, J. W., G. Spyreas, and A. G. Endress. 2009. Trajectories of vegetation-based indicators used to assess wetland restoration progress. *Ecological Applications* 19(8): 2093-2107.

Millennium Ecosystem Assessment. 2003. Ecosystems and human well-being. Washington, DC: Island Press, Vol. 200.

Miller, M. 2014. 2014 Operations, Maintenance, and Monitoring Report for Sabine Refuge Marsh Creation (CS-28). Coastal Protection and Restoration Authority of Louisiana, Coastal Protection and Restoration, Lafayette, Louisiana. 25pp.

Mushet, D. M., N. H. Euliss, and T. L. Shaffer. 2002. Floristic quality assessment of one natural and three restored wetland complexes in North Dakota, USA. *Wetlands* 22(1): 126-138.

Mortellaro, S., M. Barry, G. Gann, J. Zahina, S. Channon, C. Hilsenbeck, D. Scofield, G. Wilder, and G. Wilhelm. 2012. Coefficients of conservatism values and the floristic quality index for the vascular plants of South Florida. *Southeastern Naturalist* 11(3): 1-62.

National Marine Fisheries Service (NMFS). 2001. Little Lake Shoreline Protection/Dedicated Dredging near Round Lake Wetland Value Assessment. National Oceanic and Atmospheric Administration National Marine Fisheries Service, Baton Rouge, Louisiana.

Nichols, S. A. 1999. Floristic Quality Assessment of Wisconsin Lake Plant Communities with Example Applications. *Lake and Reservoir Management* 15(2): 133-141.

Rocchio, J. 2007. Floristic Quality Assessment Indices for Colorado plant communities. Colorado Natural Heritage Program: Colorado State University..

Sasser, C., J. Visser, E. Mouton, J. Linscombe, and S. Hartley. 2014. Vegetation types in coastal Louisiana in 2013. US Geological Survey Scientific Investigations Map, 3290(1).

Sharp, L. A. 2003. Monitoring Plan for Sabine Refuge Marsh Creation (CS-28). Lafayette, Louisiana: Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration.

Smith, R. D., A. Ammann, C. Bartoldus, and M. M. Brinson. 1995. An approach for assessing wetland function using hydrogeomorphic classification, reference wetlands, and functional indices.Technical Report WRP-DE-9. Vicksburg, MS: Waterways Experiment Station.

Stapanian, M. A., W. Schumacher, G. Gara, and S. E. Monteith. 2016. Negative effects of excessive soil phosphorus on floristic quality in Ohio wetlands. *Science of the Total Environment* 551: (556-562).

Steyer, G. D., and R. E. Stewart, Jr. 1992. Monitoring Program for Coastal Wetlands Planning, Protection, and Restoration Act Projects. U.S. Fish and Wildlife Service, National Wetlands Research Center Open File Report 9341.

Swink, F. and G. S. Wilhelm. 1979. Plants of the Chicago Region, revised and expanded edition with keys. Lisle, IL: The Morton Arboretum.

Swink, F. and G. S. Wilhelm. 1994. Coefficients of Conservatism and Floristic Quality Assessment. Plants of the Chicago Region.

U.S. Army Corps of Engineers (USACE). 2013. St. Johns Bayou New Madrid Floodway Project. Draft Environmental Impact Statement. U.S. Army Corps of Engineers, Memphis District.

U.S. Environmental Protection Agency (USEPA). 2002a. Methods for Evaluating Wetland Condition: Using Vegetation to Assess Environmental Conditions in Wetlands. EPA-822-R-02-020. Washington, DC: U.S. Environmental Protection Agency, Office of Water.

U.S. Environmental Protection Agency (USEPA). 2002b. *Wetland monitoring and assessment: A technical framework*. EPA 843-F-02-002(h). Washington, DC: US Environmental Protection Agency.

Votteler, T. H. and T. A. Muir. 1996. Wetland Management and Research Wetland Protection Legislation. National Water Summary on Wetlands Resources. United States Geological Survey Water Supply Paper 2425.

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14. ABSTRACT

Restoration efforts in the United States have created or benefitted large expanses of wetlands. Typical goals of wetland restoration efforts are to conserve, create, or enhance wetland form and to achieve wetland function that approaches natural conditions. Measures of wetland condition have been used to monitor and assess project performance, resilience, and adaptive management needs. An emerging tool for performing bioassessments in wetland systems is the Floristic Quality Index (FQI). This study assessed the use of a modified FQI (FQI_{mod}) to evaluate site development, plant community establishment, and wetland condition. Three restoration sites in coastal Louisiana were used to evaluate the utility of an FQI_{mod} for assessing the performance and resilience of restored wetlands by comparison to reference wetlands. Results demonstrate that the FQI_{mod} data successfully reflected large disturbance events — namely hurricanes and salinity spikes. The data also identified vegetation differences due to elevation, age, and hydrology. The modified FQI provided useful measures of restoration type (e.g., planted versus not planted, marsh creation versus nourishment), chronosequence (condition and stability over time), and trajectory (i.e., intersecting trend lines when restored marsh FQI approaches reference marsh condition). The FQI_{mod} provides a rapid and effective system for assessing wetland condition and performance.

15. SUBJECT TERMS

	Floristic Quality	Wetland Restoration
Ecosystem Resilience	Adaptive Management	Bioassessments
Wetland Condition	Coefficient of Conservatism	Restoration ecology
Wetlands – Louisiana	Environmental management	

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